International Journal of Ecosystem 2015, 5(3A): 93-96
DOI: 10.5923/c.ije.201501.14

Vulnerability of Groundwater in Three Megacities of India

Sanghamitra Adhya

Assistant Professor in Geography, Kalyani Mahavidyalaya, Nadia, West Bengal

Abstract Groundwater is an important part of the water resources for human use. It is an integral part of the Hydrological cycle and is valuable source of drinking water. It is mainly governed by geological formations, climatic conditions, the nature and extent of aquifer bodies, hydro geological properties and groundwater flow characteristics. Aquifers are quite sensitive to contamination and over-exploitation. Growth of population in cities coupled with lack of scientific knowledge lead to lower down ground water table. Investigations conducted in Kolkata, Delhi and Mumbai for the last 20 years reflect alarming depletion of piezometric level (14-16 metres below ground level in many places). There is indiscriminate use of groundwater in the megacities of India without simultaneous efforts of recharge. Due to deforestation, urbanization and absence of planned water management, much of rainwater goes untapped directly to the sea without recharging the groundwater. In India there are no legal standards of maximum allowable pollution and no data on the capacity of receiving streams to adsorb pollution loads without adverse environmental impact. In Kolkata, Mumbai and Delhi, part of the untreated sewage goes directly into the river or sea. The incidences of water related deaths and diseases are increasing in and around Indian megacities at an alarming rate. The crisis is human-induced which leads to increased pollution of surface water, groundwater and environmental degradation. There is need for the fundamental reforms on how to capture water, allocate it among sectors, manage and deliver it to users in sustainable way.

Keywords Groundwater depletion, Contamination, Artificial recharge, Rain water harvesting

1. Introduction

Groundwater is a primary source of fresh water in many parts of the world. Some regions are becoming overly dependent on it, consuming groundwater faster than it is naturally replenished and causing water tables to decline unremittingly. Indirect evidence suggests that this is the case in northwest India, but there has been no regional assessment of the rate of groundwater depletion. Due to deforestation, urbanization and absence of planned catchment management, much of rainwater goes untapped directly to the sea without recharging the groundwater. During monsoon, floods arise and cause havoc and in summer after runoff there develops widespread water scarcity. Delhi, Mumbai and Kolkata are the most populated metropolitan cities of India. For the last 300 years these cities have experienced huge population growth. Due to huge development and increase in population demand of water for domestic purpose mainly has increased by many folds.

* Corresponding author:
dr.sanghamitraadhya@yahoo.in (Sanghamitra Adhya)
Published online at http://journal.sapub.org/ije

2. Problem

Terrestrial water storage-change observations from the NASA Gravity Recovery and Climate Experiment satellites and simulated soil-water variations from a data-integrating hydrological modelling system found that groundwater is being depleted at a mean rate of 4.0 ± 1.0 cm yr^{-1} equivalent height of water (17.7 ± 4.5 km^3 yr^{-1}) over the Indian states of Rajasthan, Punjab and Haryana (including Delhi) and some parts of West Bengal (including Kolkata).

A groundwater survey conducted by the Central Pollution Control Board in 22 problem areas of the country has revealed that rapid industrialization of towns coupled with urbanization has led to "merciless misuse" of the groundwater resource resulting in contamination at an all time high. Also industrial and domestic waste, pesticide residues tended to be higher in ground water compared to surface water as the soil acts as a reservoir for pesticides and heavy metals which can steadily transfer them to the groundwater.

It is estimated that 70% of India's groundwater and surface waters are of doubtful quality (Bobba *et al.*, 1997). In Kolkata, Mumbai and Delhi, part of the untreated sewage

goes directly into the river or sea creating serious environmental problems. The status of disposal according official figures of 20 major cities in India revealed that nine cities- Kanpur, Banglore, Pune, Nagpur, Lucknow, Agra, Varanasi, Madurai and Allahabad had no sewage treatment plants. Only two cities – Ahmedabad and Delhi had modern sewage treatment plants. In India there are no legal standards of maximum allowable pollution and no data on the capacity of receiving streams to adsorb pollution loads without adverse environmental impact (National Environmental Engineering Research Institute, 1994).

3. Depth to Water Level Condition

Delhi ($28^{o}34^{/}$ N, $77^{o}12^{/}$ E), is the National Capital, known as the capital territory of India. It has a population of about 11 million and a metropolitan population of about 16.3 million, making it the second most populous city in India. Such is the nature of urban expansion in Delhi that its growth has expanded beyond the NCT to incorporate towns in neighbouring states and at its largest extent can count a population of about 25 million residents as of 2014. Scientists at the premier National Geophysical Research Institute (NGRI) have calculated that groundwater in Hyderabad, Delhi, Mumbai and Chennai, along with several other northern cities, are declining at such a rapid pace that in ten years these cities will be almost dry. Delhi has 162 hydrograph monitoring stations, ranging from one monitoring station per 1.4 sq km in the New Delhi district to a monitoring station for every 30 sq km in the North and East district. The Central Groundwater Board's (CGB) data shows that south Delhi had used up 8,292 HAM (hectare meter) of water while the actual recharge from various sources, mostly rains, was 4,123 HAM. In south-west and west Delhi, the use of groundwater was 12,569 HAM and 4,172 HAM, respectively, against the recharge of 9,127 and 2,652 HAM only. “The data indicates that south and southwest districts are showing falling trends”. Moreover the maximum decadal fall is recorded in north-west, south and south-west districts-9.76 to 14.07 metre on mean levels in the month of May. With some exceptions of north and north-east Delhi, all other seven districts fall in the "over-exploited" zone with south Delhi faring the worst. Things are almost equally bad in east Delhi, whose net groundwater usage was 2,208 HAM against the recharge of 1,284 HAM.

Mumbai ($18^{o}53^{/}$ N, $72^{o}48^{/}$ E) is the capital of the Indian state of Maharashtra. It is the most populous city in India, and the eighth most populous city in the world, with an estimated city population of 18.4 million and metropolitan area population of 20.7 million as of 2011. Central Ground Water Board periodically monitors 5 National Hydrograph Network Stations (NHNS) in Mumbai, four times a year i.e. January, May (Premonsoon), August and November (Postmonsoon). The premonsoon depth to water levels monitored during May 2011 ranges between 2.77 m bgl (Church Gate) and 6.42 m bgl (A.M.C. Colony). The shallow water levels between 2 and 5 m bgl are observed in southern part, whereas moderate water levels in the range of 5 to 10m bgl are observed in northern part of the area. The depth to water levels during postmonsoon (Nov. 2011) ranges between 1.80 m bgl (Church Gate) and 7.10 m bgl (A.M.C. Colony). The water levels in major part of the district range between 2 and 5 m bgl. Shallow water levels of < 2 m bgl are observed in small area in southern part, whereas water levels of 5 to 10 m bgl are observed in north central part of the district. Seasonal water level fluctuation between premonsoon and postmonsoon of 2011 have been computed. The rise in water levels in the range of 0.97 (Church Gate) to 1.85 m are observed, whereas fall in water level of 0.68 is observed at 1 NHNS located at A.M.C. Colony. In major part of the district rise within 2 m is observed, rise of 2 to 4 m is seen in extreme northern parts of the district, whereas fall of up to 2 m is observed in north central part of the district.

Kolkata ($22^{o}36^{/}$ N, $88^{o}24^{/}$ E) is the capital of the West Bengal. Located on the east bank of the Hooghly River, it is the principal commercial, cultural, and educational centre of East India, while the Kolkata Port is India's oldest operating port as well as its sole major riverine port. As of 2011, the city had 4.5 million residents; the urban agglomeration, which comprises the city and its suburbs, was home to approximately 14.1 million, making it the third-most populous metropolis in India. Due to heavy exploitation of groundwater a major change has been occurred in the water level condition of Kolkata. Investigations conducted in Kolkata for the last 20 years reflect alarming depletion of piezometric level. At present the piezometric level is 16 to 18 metres below ground level in the Alipur, Babughat, Ballygunge, Kalighat, Park circus area whereas in the Bansdroni and surrounding areas this level is 11 to 13 metre deep. At Garia and surrounding areas the piezometric level is between 10 and 12 metre below ground level. In the north at Baguihati, Sinthi, and Beleghata area water level in pre monsoon period is 14 to 16 metre below ground level, whereas in dumdum and surrounding area this level is from 12 to 14 metre bgl. Piezometric level is at a depth of 8 to 12 metre below sea level on an average. During the post monsoon period piezometric level rises to the tune of 1 to 1.5 metre in Alipur and about 2 metres in Bansdroni and Garia and in north Kolkata and Dumdum.

4. Contamination of Groundwater

Materials from the land's surface can move through the soil and end up in the groundwater. Pesticides and fertilizers can find their way into groundwater supplies over time. Road salt, toxic substances from mining sites, and used motor oil also may seep into groundwater. In addition, it is possible for untreated waste from septic tanks and toxic chemicals from underground storage tanks and leaky landfills to contaminate groundwater and cause it to become unsafe and unfit for human use. Diseases such as hepatitis and dysentery may be caused by contamination from septic tank waste. Poisoning

may be caused by toxins that have leached into well water supplies. Wildlife can also be harmed by contaminated groundwater. Other long term effects such as certain types of cancer may also result from exposure to polluted water.

A study has found traces of chromium, zinc, cadmium and copper in areas around Dhapa (Kolkata). Copper and cadmium above permissible limits was also recorded. Under pressure are the East Calcutta Wetlands (ECW), the city's natural and the only sewage treatment system, located near Dhapa. Sewage of the entire city collects at ECW along with industrial waste from tanneries, battery and jewellery factories. These wastes contain heavy metals whose load is so high that the wetlands can't filter all of it. In Kolkata more than 300 µg/L arsenic concentrations were found in tubewells are categorized as severely affected. For the last 300 years Kolkata has experienced a huge population growth. Of the 141 wards that the city is divided into, as many as 77 have “high levels” of arsenic in groundwater, shows a study by the School of Environmental Studies (SOES) of Jadavpur University.

Due to huge development and increase in population demand of water for domestic purpose mainly has increased by many folds. Extensive extraction of groundwater mainly from shallow aquifers cause recharge from nearby surface water bodies. Infiltration of recharge water enriched in dissolved organic matter derived either from recently accumulated biomass and/or from sediment organic matter enhanced reductive dissolution of hydrated iron oxide that are present mainly as sediment grain coatings in the aquifers enhancing release of adsorbed arsenic to groundwater (Mukherjee et al 2007). A sample of water drawn from a tube well in Lake Gardens, showed arsenic content of 825µg/L. That’s more than 16 times the maximum permissible limit. Ideally it should be less than 10µg/L, says WHO.

Inadequate sewage treatment and disposal in the national capital territory is contaminating groundwater of Delhi. It is also well known that there are 27 urban villages, 150 rural villages and 1,575 unauthorised colonies which are yet to be connected to the sewer network. Therefore, approximately 35 per cent of the sewage treatment facilities, woefully inadequate, is currently under-utilised, and roughly 2,900 million litres of sewage is discharged untreated into the 19 major stormwater drains and ultimately into the river Yamuna.

The latest data of the Central Ground Water Board (CGWB) shows that groundwater samples taken from observation wells in the national capital are getting contaminated because of their unhygienic catchments and untreated sewage, which is discharged in the open and into drains, and percolates into the groundwater. Nitrate concentrations in the water samples, known to cause methaemoglobinemia or blue baby syndrome (a blood disorder wherein hemoglobin is unable to release oxygen effectively to body tissues), have been recorded at a high 1,500 mg/l. The World Health Organisation advice is that nitrate levels in drinking water should be below 50 mg/l, as “an effective preventive measure”. The Bureau of Indian Standards states that the desirable limit is 45 mg/l, and there is “no relaxation” for this maximum value. The CGWB report, compiled in November last year, states that “the nitrate pollution in the groundwater is mostly anthropogenic and may be due to improper disposal of sewage and unhygienic conditions around the well”. CGWB also monitored the electrical conductance of water to get an idea of the mineral content in groundwater, as well as the total dissolved salts content of a water sample. Out of the total 124 analysed samples, 42 samples were recorded with values in the range of 2,000 - 16,700 µs/cm. But it is the rising nitrate levels that are alarming. The levels have been attributed to “combined effect of contamination from domestic sewage, livestock rearing, landfills and runoff from fertilized fields, unlined drains and cattle sheds”. According to the report, Delhi’s groundwater has more nitrate contents at shallow levels but they decrease with depth, substantiating the argument that levels are high where “domestic effluent is discharged into open unlined drains”.

The chemical analysis shows that the ground water in and around Mumbai is alkaline in nature. The concentration of major ions indicates that among the cations, the concentration of sodium and magnesium ion is almost same followed by calcium, while among the anions the concentration of bicarbonate ion is highest, followed by chloride, sulphate and nitrate ions. There are thousands of industrial units of various types. These industries cause pollution to ground water and even to surface water. Besides this the city is heavily populated, at very high population density the sanitation facility is quite inadequate which has given rise to nitrate pollution in the district. The special studies in Chembur area reveals presence of Cu, Cr, Ca, As, Hg in ground water which are extremely harmful.

5. Recommendations

There is a good scope for rainwater harvesting in these areas. A net quantum of 200-250 mil m^3 of available rainwater may be utilized by both conservation and artificial recharge. Ground water exploitation for commercial purpose needs to be regulated. Due to critical ground water condition in Kolkata metropolitan areas indiscriminate withdrawal of ground water is to be restricted. If necessary, the area is to be notified by legal means. Emphasis is to be given to lower the stress on ground water development by covering more and more area under pipe water supply (treated surface water). Regular monitoring of both ground water level and quality of ground water is to be done. This will help to understand the change in piezometric surface consequent to withdrawal of ground water and the change in quality of ground water and to identify the tube wells affected by arsenic or any other chemical and/ or biogenic contamination. The tube wells affected by any short of pollution should be discarded. Ground water from open wells wherever present may be used for domestic purposes after proper treatment.

The ground water resources of 7 districts of NCT, Delhi are over-exploited with maximum fall reaching to even

20-27 metre in south district. Moreover, the presence of saline aquifers below a depth of 30 to 40 m further limits the development of ground water resources. Thus the complex ground water regime of NCT, Delhi needs scientific planning to make the ground water resources as sustainable supplement source of water supply in NCT, Delhi.

The Master plan for rainwater harvesting and artificial recharge of National Capital Territory (NCT) of Delhi estimated that nearly 440 MCM of rainwater can be harvested annually in Delhi and utilized for artificial recharge to groundwater. The artificial recharge to groundwater can be taken up by adopting different measures like rainwater harvesting at the level of individuals, at the level of colonies and by the institutions. The Central Groundwater Board of NCT Delhi has taken up the leadership of spearheading rainwater harvesting in NCT Delhi. The rainwater harvesting effort by CGWB in JNU and IIT campuses resulted in to rise in water level to the tune of about 2 to 3 meters in vicinity of the area where the project was implemented. Similar rainwater harvesting effort in President Estate resulted in the rise of water level in the range of 1 to 4 meters in the vicinity of the areas where the project was implemented.

In the alluvial areas of Mumbai shallow dugwells (5 to 10 m), whereas in Deccan Trap Basalt areas dugwells (7 to 15 m) are the most feasible structures for ground water development. About 500 to 800 wells can be constructed if the yield of wells is considered to be 30-50 m3/day. The scope exists for constructing suitable artificial recharge structures in limited areas located in north central part of the district like recharge shafts/borewells. The existing dugwells/borewells can also be used for artificial recharge, however, the source water should be properly filtered before being put in the wells. Roof top rain water harvesting is also feasible by storing rainwater in storage tanks in areas with shallow water levels, thereby supplementing the main source of water. The conjunctive utilization of available surface and ground water in systematic and planned way will be the best solution for meeting present and future demands of water.

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